

1 Characterization of the Ozone Weekend Effect in California

1.2 The Weekend Ozone Effect During Ozone-Conductive Days in the South Coast Air Basin

1.2.1 Abstract/summary

With ozone known to be higher during the weekends compared to weekdays at many sites in the South Coast Air Basin, this study attempts to investigate whether the basinwide maximum 1-hour daily concentrations behave differently on days considered highly conducive for ozone formation as compared to all days. Using meteorological conditions to predict daily maximum-hour ozone concentrations, we classify approximately one-third of the days during May through October of 1992-1994 and 1996-1998 to be highly conducive and compare the day-of-week pattern of mean ozone concentrations adjusted for trend and seasonality. Preliminary results show the basinwide maximum ozone to behave similarly during the weekend on all days and highly ozone-conductive days – increasing from Friday to Saturday, remaining almost the same on Sunday, then decreasing on Monday. Approximate confidence intervals indicate strong evidence of this “weekend effect” for all days. However, for highly ozone-conductive days, the available data and methods do not sufficiently resolve differences between days of the week.

1.2.2 Introduction/background

Austin and Tran (1999) characterized the behavior of ambient ozone concentrations in three metropolitan regions of California. That work considered all days during the ozone season and clearly shows ozone to significantly increase during the weekend and decrease at the start of the weekdays at many sites. In this chapter, we attempt to describe the weekend effect of ozone in the South Coast Air Basin during ozone-conductive days. Further, we evaluate whether ozone behaves differently than it does when analyzed across all days.

1.2.3 Methodology

We consider the basinwide daily 1-hour maximum ozone concentrations during two periods around the Cleaner-Burning Gasoline (CBG) program: 1992-1994 (pre-CBG) and 1996-1998 (post-CBG). Wherever possible, we follow the methods used in Austin and Tran (1999).

To remove nuisance sources of variation, we fit a smoothed (spline) line to basinwide ozone maximum concentration from all days (365 days in each year) and obtain adjusted (residual) concentrations by subtracting smoothed values from observed concentrations.

June 30, 2003

Next, we isolate only ozone season, May 17 – October 15, and compute the mean adjusted (residual) concentrations by day of week (DOW) for all days in the ozone season. This information will be considered as the base ozone behavior for all days.

To assess the atmosphere's conduciveness for ozone formation, we use Lawrence C. Larsen's equations (1998) for predicting basinwide daily 1-hour maximum ozone based on meteorological conditions in the basin (surface and aloft temperatures). Since these equations were developed for basinwide maximum concentrations, our results could not be compared directly with previous work on site-specific DOW patterns (Austin and Tran, 1999).

Next, we stratify days into three groups of ozone-conducive levels based on predicted ozone: Low (≤ 0.12 ppm), Medium (or Moderate, >0.12 ppm but ≤ 0.16 ppm), and High (> 0.16 ppm). This stratification results in approximately equal number of data points in each group.

Similar to the analysis of All Days, we compute the mean adjusted ambient concentrations by DOW for each group. In contrast to the percent changes in concentration from day to day done in Austin and Tran (1999), these means are intended for comparing patterns rather than testing for statistical significance. Hence, only approximate confidence intervals are computed (see section 1.2.4.5).

To assist us in comparing patterns of ozone behavior, we plot the means between groups, across All Days, and between pre-CBG vs post-CBG periods.

1.2.4 Results/discussion

1.2.4.1 About tables and figures

Table 1.2-1 lists the mean residual concentrations and their standard deviations for each of the 4 categories in the pre-CBG period: High, Low, Medium (moderate), and All Days. Table 1.2-2 lists similar information for the post-CBG period.

Figure 1.2-1 is a scatterplot of the basinwide daily maximum 1-hour ozone concentration in the pre-CBG period, with the "smoothed" line superimposed. Figure 1.2-2 displays similar information for the post-CBG period.

Figure 1.2-3 displays the means from Table 1.2-1 in graphical form. Figure 1.2-4 displays those from Table 1.2-2.

Figure 1.2-5 displays the approximate 90% confidence intervals around the DOW means from Table 1.2-1 for the High group and All Days. Figure 1.2-6 displays similar info from Table 1.2-2.

1.2.4.2 1992-1994 Results

In the pre-CBG period, the Low and High groups show ozone to decrease from Thursday to Friday and to increase similarly on Saturday and Sunday (Figure 1.2-3). But for the Medium group, ozone increases from Thursday to Friday, followed by a steep increase on Saturday and a decrease on Sunday.

Saturday ozone was greater than Friday ozone by 0.009 ppm when ozone forming potential was high but 0.029 ppm greater when ozone forming potential was moderate.

Weekend average ozone was greater than weekday average ozone by 0.008 ppm when ozone forming potential was high but 0.023 ppm greater when ozone forming potential was moderate.

1.2.4.3 1996-1998 Results

In the post-CBG period, the Low group shows ozone to increase from Thursday to Friday, followed by increases on Saturday and Sunday – as in the pre-CBG period (Figure 1.2-4). For the Medium group, ozone decreases from Thursday to Friday, then followed by a weekend behavior similar to pre-CBG period. For the High group, ozone decreases from Saturday to Sunday in post-CBG period; it increases in the pre-CBG period.

Saturday ozone was greater than Friday ozone by 0.016 ppm when ozone forming potential was high but 0.021 ppm greater when ozone forming potential was moderate.

Weekend average ozone was greater than weekday average ozone by 0.019 ppm when ozone forming potential was high but 0.017 ppm greater when ozone forming potential was moderate.

1.2.4.4 Results for High ozone-conductive days

During High ozone-conductive days in both periods, ozone tends to rise during the week to a peak on Thursday, then decreases on Friday before exhibiting the typical weekend pattern. Whether this increase on Thursday is significant requires further investigation.

Overall, we see the weekend pattern for the High group is similar to that across All Days, unlike the Medium group. That is, in both periods, the typical weekend pattern of ozone -- increasing from Friday to Saturday, remaining almost the same on Sunday, then decreasing from Sunday to Monday – exists in High ozone-conductive days as well as All Days.

Whereas in Austin & Tran (1999), Sunday ozone was highest compared to other days after CBG for many sites, the “Sunday effect” does not exist in basinwide maximum for the High group.

1.2.4.5 On approximate statistical significance

Note that no formal statistical significance testing was conducted; the focus is on estimation rather than inference. Tables 1.2-1 and 1.2- 2 indicate standard errors (standard deviations of the mean) approximately equal to 0.007 ppm for High group and 0.004 ppm for All Days. These standard errors lead to the computation of approximate confidence intervals for each mean. However, a formal test for significant differences between days would need to account for the correlation between days rather than assuming independence. Since the correlation is positive, the standard errors in Tables 1.2-1 and 1.2-2 are greater than they would be if the correlation were correctly removed from the data. Nevertheless, approximate confidence intervals may give us further insight.

Figures 1.2-5 and 1.2-6 display approximate 90% confidence intervals for the mean ozone residual concentrations by DOW in the pre-CBG and post-CBG periods, respectively. When the bars do not overlap, there is strong evidence of a significant difference between days. On the other hand, if they do overlap, it does not imply that the DOW means are “the same”. The available data combined with our current methods may not be able to resolve any differences clearly.

Based on the approximate intervals in Figures 1.2-5 and 1.2-6, we can see that the weekend effect strongly exists for All Days in both periods, with Friday increasing to Saturday and Sunday decreasing to Monday (and no significant differences between weekdays). The evidence for a weekend effect is not as clear in the High group; no day is significantly different from the others.

1.2.5 Conclusion/implication

Some days have meteorological conditions conducive to high ozone concentrations while other days do not. In the South Coast Air Basin, days with high barometric pressure and high surface temperatures tend to have high ozone concentrations somewhere in the basin.

A statistical model was developed to relate the highest ozone in the basin on a given day to selected meteorological parameters for the same day. Based on data from 1992 through 1994, this model was calibrated to produce “meteorologically standardized” ozone concentrations. Days with meteorological data that produce similar met-standardized ozone values are considered to have similar ozone-forming potential. Weekdays and weekend days within categories of high, moderate, and low ozone-forming potential were compared to each other. In 1996, the average maximum ozone on days with “moderate” ozone-forming potential was approximately 0.120 ppm. However, the average maximum ozone on days with “high” ozone-forming potential was approximately 0.150 ppm.

Using data from 1992-1994 (Figure 1.2-3), Saturday ozone was greater than Friday ozone by 0.009 ppm when ozone forming potential was high but 0.029 ppm greater when ozone forming potential was moderate. Weekend average ozone was

June 30, 2003

greater than weekday average ozone by 0.008 ppm when ozone forming potential was high but 0.023 ppm greater when ozone forming potential was moderate. Furthermore, weekend ozone was about the same as Thursday (the weekday with the highest ozone) when ozone forming potential was high, but weekend ozone was substantially higher than Thursday ozone when ozone-forming potential was moderate.

Using data from 1996-1998 (Figure 1.2-4), Saturday ozone was greater than Friday ozone by 0.016 ppm when ozone-forming potential was high but was 0.021 ppm greater when ozone forming potential was moderate. Weekend average ozone was greater than weekday average ozone by 0.019 ppm when ozone forming potential was high but was 0.017 ppm greater when ozone forming potential was moderate. Furthermore, weekend ozone was about the same as Thursday (the weekday with the highest ozone) when ozone forming potential was high, but weekend ozone was substantially higher than Thursday ozone when ozone-forming potential was moderate.

An important implication of these results is the difference in ozone on weekdays compared to weekends is relatively small (less than 10%) on those days that determine whether the South Coast Air Basin attains national or state standards for ozone. Hence, the ozone weekend effect does not necessarily indicate that attaining standards on weekends will be substantially more demanding than attaining them on weekdays.

1.2.6 Recommendation

The results from this study are based on approximate confidence intervals. A more careful investigation that accounts for all sources of variation in the data would warrant more definitive conclusions. Other methods of determining ozone-conduciveness could also be explored.

1.2.7 References

Austin, J. and H. Tran (1999) "A characterization of weekday-weekend ambient ozone concentrations in California," *Proceedings of the 7th International Conference on Air Pollution*, July 27-29, Palo Alto, California.

Lawrence C. Larsen (1998) "Cleaner-Burning Gasoline: An Assessment of Its Impact on Ozone Air Quality in California", January.

June 30, 2003

Table 1.2-2. Mean residual ozone concentrations by ozone formation potential*, 1992-1994.

1992-94 Group	Day of Week	No. of Observations	Mean Residual Concentration	Standard Deviation of Mean
High	Sunday	24	0.0292	0.0069
High	Monday	21	0.0223	0.0071
High	Tuesday	22	0.0084	0.0068
High	Weds.	24	0.0194	0.0071
High	Thursday	23	0.0289	0.0077
High	Friday	27	0.0175	0.0090
High	Saturday	24	0.0265	0.0095
Low	Sunday	28	-0.0113	0.0087
Low	Monday	28	-0.0275	0.0067
Low	Tuesday	26	-0.0266	0.0052
Low	Weds.	27	-0.0246	0.0062
Low	Thursday	28	-0.0215	0.0053
Low	Friday	21	-0.0270	0.0058
Low	Saturday	24	-0.0160	0.0071
Medium	Sunday	22	0.0054	0.0085
Medium	Monday	25	-0.0111	0.0082
Medium	Tuesday	26	-0.0104	0.0060
Medium	Weds.	23	-0.0029	0.0062
Medium	Thursday	23	-0.0065	0.0057
Medium	Friday	26	-0.0027	0.0052
Medium	Saturday	26	0.0267	0.0078
All Days	Sunday	74	0.0068	0.0051
All Days	Monday	74	-0.0078	0.0048
All Days	Tuesday	74	-0.0105	0.0038
All Days	Weds.	74	-0.0036	0.0043
All Days	Thursday	74	-0.0012	0.0043
All Days	Friday	74	-0.0022	0.0046
All Days	Saturday	74	0.0128	0.0052

* High – predicted [O₃] > 0.16 ppm
Medium – 0.12 ppm < predicted [O₃] # 0.16 ppm
Low - predicted [O₃] # 0.12 ppm

June 30, 2003

Table 1.2-3. Mean residual ozone concentrations by ozone formation potential*, 1996-1998.

1996-98 Group	Day of Week	No. of Observations	Mean Residual Concentration	Standard Deviation of Mean
High	Sunday	25	0.0246	0.0070
High	Monday	22	0.0027	0.0055
High	Tuesday	25	0.0121	0.0056
High	Weds.	24	0.0200	0.0063
High	Thursday	22	0.0244	0.0077
High	Friday	23	0.0112	0.0056
High	Saturday	22	0.0275	0.0054
Low	Sunday	27	-0.0036	0.0041
Low	Monday	31	-0.0154	0.0037
Low	Tuesday	27	-0.0164	0.0036
Low	Weds.	27	-0.0139	0.0044
Low	Thursday	31	-0.0167	0.0047
Low	Friday	29	-0.0137	0.0045
Low	Saturday	26	-0.0119	0.0045
Medium	Sunday	22	0.0079	0.0062
Medium	Monday	21	-0.0047	0.0044
Medium	Tuesday	22	-0.0119	0.0056
Medium	Weds.	23	-0.0103	0.0055
Medium	Thursday	21	-0.0035	0.0049
Medium	Friday	22	-0.0076	0.0049
Medium	Saturday	26	0.0134	0.0052
All Days	Sunday	74	0.0094	0.0036
All Days	Monday	74	-0.0070	0.0027
All Days	Tuesday	74	-0.0055	0.0032
All Days	Weds.	74	-0.0018	0.0035
All Days	Thursday	74	-0.0007	0.0038
All Days	Friday	74	-0.0041	0.0031
All Days	Saturday	74	0.0087	0.0034

* High – predicted [O₃] > 0.16 ppm
Medium – 0.12 ppm < predicted [O₃] # 0.16 ppm
Low - predicted [O₃] # 0.12 ppm

June 30, 2003

Figure 1.2-1. Basinwide daily maximum 1-hour ozone concentration (in ppm) with smoothed line superimposed. South Coast Air Basin during 1992-94

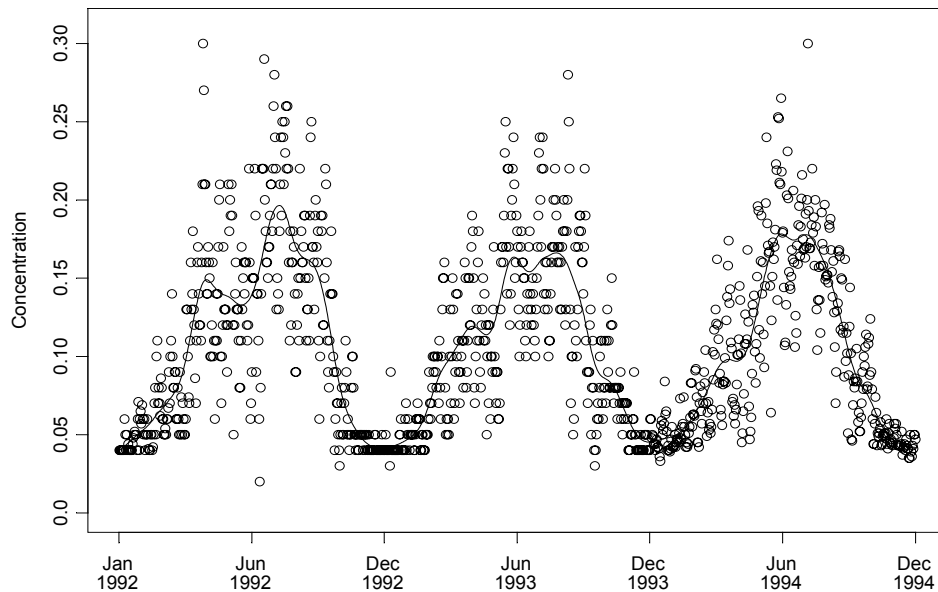
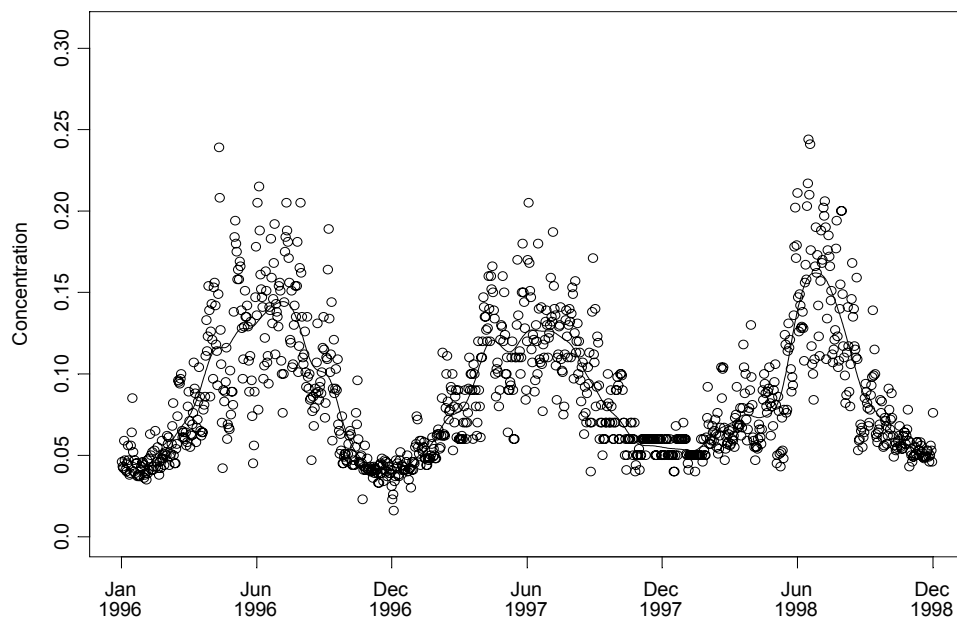


Figure 1.2-2. Basinwide daily maximum 1-hour ozone concentration (in ppm) with smoothed line superimposed. South Coast Air Basin during 1996-98



June 30, 2003

Figure 1.2-3. Mean residual ozone concentrations by day of week, 1992-1994.

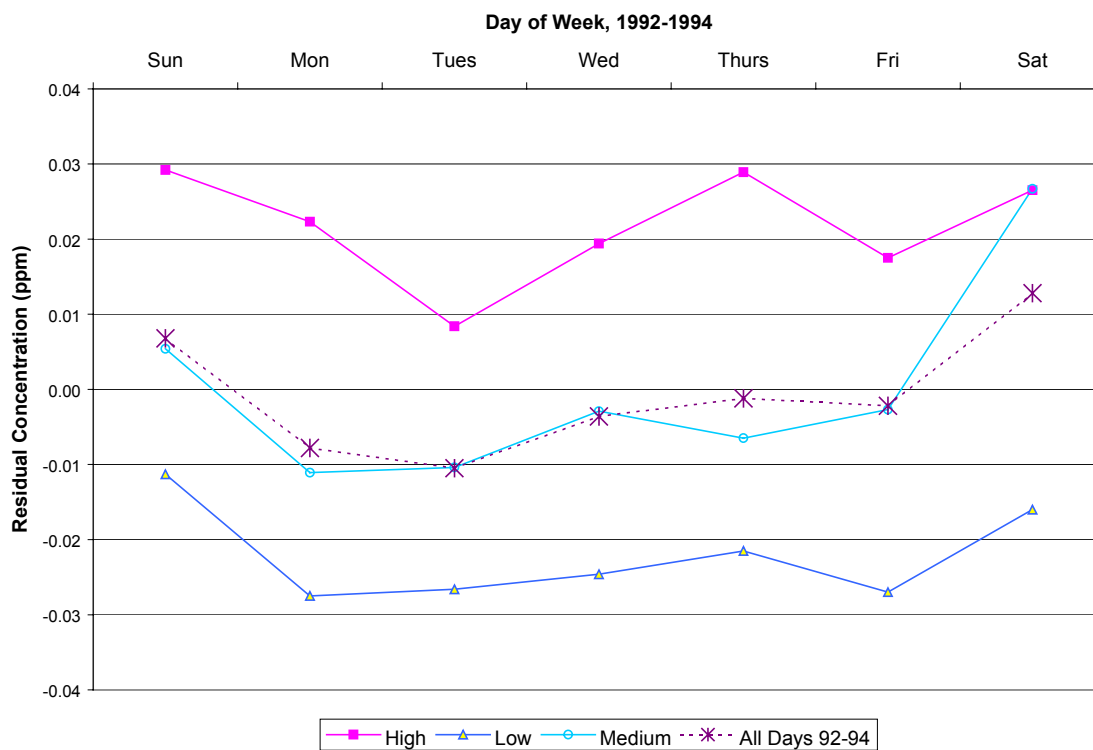
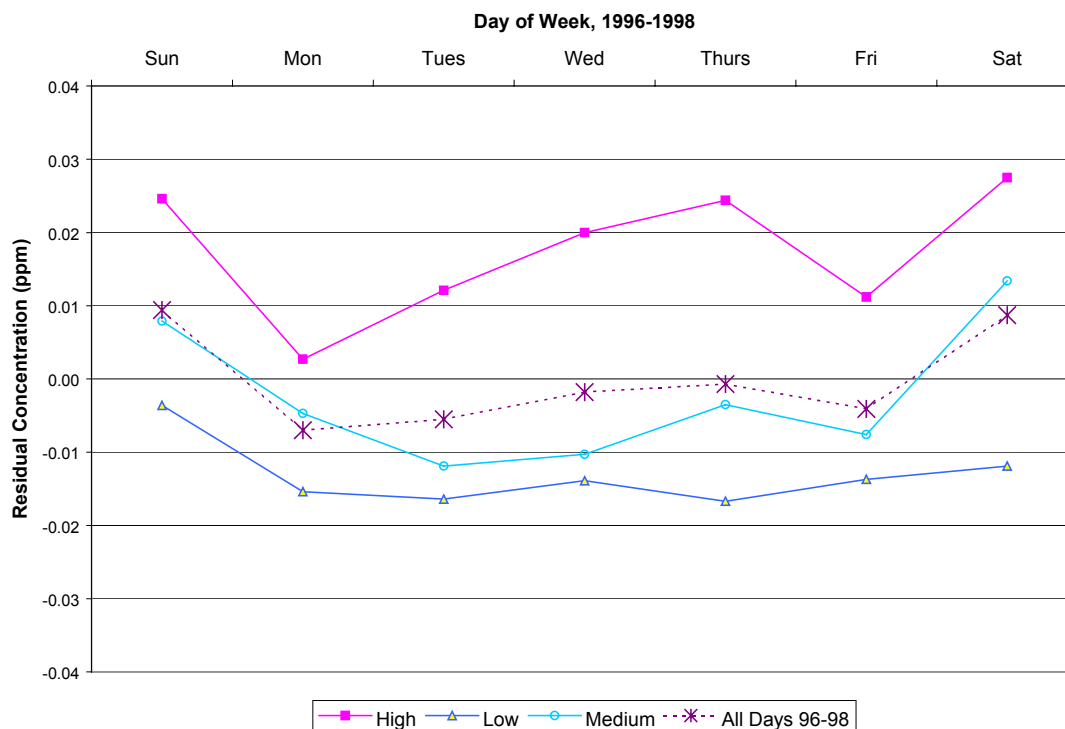


Figure 1.2-4. Mean residual ozone concentrations by day of week, 1996-1998.



June 30, 2003

Figure 1.2-5. Approximate 90% confidence intervals for mean residual ozone concentrations on highly ozone-conductive days and all days combined, 1992-94.

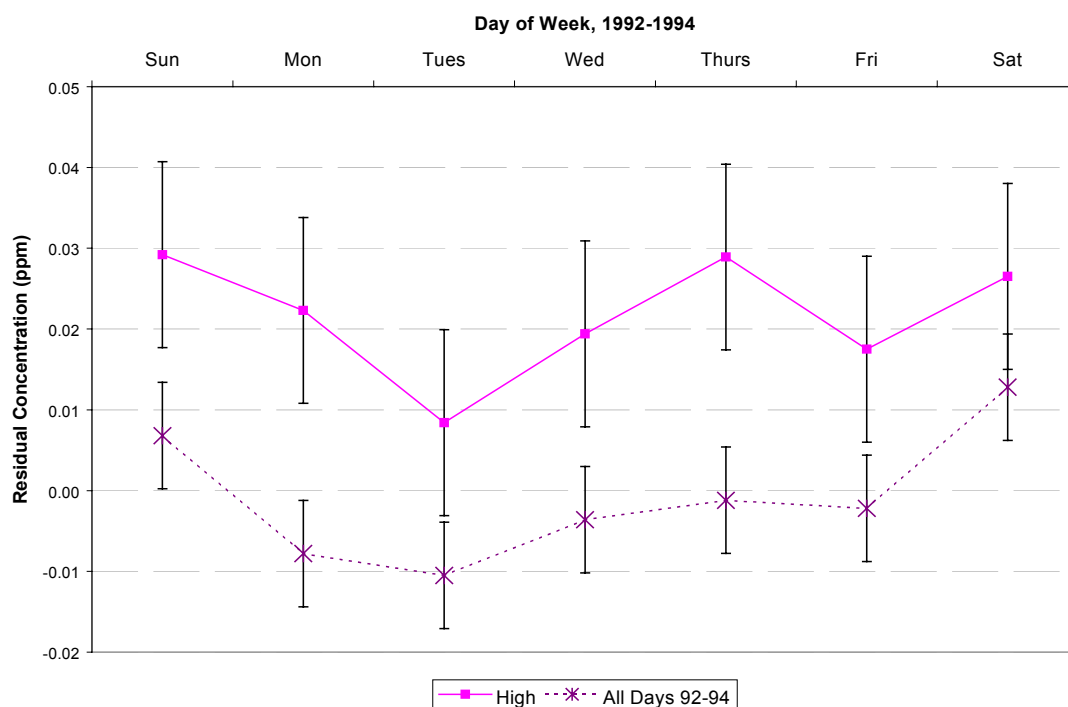


Figure 1.2-6. Approximate 90% confidence intervals for mean residual ozone concentrations on highly ozone-conductive days and all days combined, 1996-98.

